FINAL

Combining the Best Attributes of Qualitative and Quantitative Risk Management Tool Support

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Abstract

Tools have been developed that support risk identification and management activities during different phases of a project lifecycle. For the earlier stages of the project lifecycle, a tool for qualitative identification and manipulation of risk and risk mitigation data was developed. For the later stages of the lifecycle, a separate tool for quantitative manipulation of requirements, risk and risk mitigation data was developed. These two tools were then combined into a single tool.

The combination of these qualitative and quantitative risk management tools is the focus of this paper. The combination was first envisioned as simply a convenience, ensuring that the results from the early lifecycle risk management would flow smoothly into the later lifecycle management. However, it was found that the combination led to the possibility of extending many of the capabilities of each tool into the other tool's phases. The net result is a combination that exhibits the best attributes of both qualitative and quantitative risk management tool support.

1. Introduction

Risk management is a critical activity in the cost-effective design, implementation and operation of complex projects. NASA is pioneering the management of risk as a *resource*, one that can be traded against other resources such as schedule, cost and performance [1]. Successful risk management involves identification of sources of risk, estimation of the impact and likelihood of risks, decisions of what levels of risks to accept, and choice of means to mitigate risks. NASA is developing tools, techniques and knowledge to support these risk management activities.

For spacecraft flight projects, the earlier project phases address conceptual design, costing, planning and requirements. During these earlier phases, risk management is primarily *qualitative* in nature. Based on the available information, the risks that can be addressed are categories of risk elements (thermal issues, timing and latency issues, etc.) and are generally high-level. The later project phases address subsystem design, detailed requirements, design models, manufacturing models, and actual construction and operation. During these later phases, risk management becomes primarily *quantitative* in nature. Identified risks are now more detailed and focus on specific issues, which allow for specific solutions. Software tool support for risk management has mirrored this qualitative/quantitative split.

The authors have been involved in the development of two such risk management software tools:

- An early-phase, qualitative tool called Risk Balancing Profile (RBP) [2]. It manipulates qualitative (or higher, conceptual level) representations of risk, risk mitigations activities, etc.
- A later-phase, quantitative tool called Defect Detection and Prevention (DDP) [3]. It manipulates quantitative representations of a superset of RBP's information.

Both tools serve as intelligent decision aids to a set of experts and are capable of handling non-trivial amounts of data - enough to render use of a generic tool, such as a spreadsheet, ineffective (see [4] for details of DDP's capabilities in this regard). The focus of this paper is the combination of these two tools.

2. Combining the Qualitative and Quantitative Tools

The combination of RBP and DDP was originally conceived of as simply a convenience to smooth the transfer of risk management data accumulated in the earlier-lifecycle-phases' use of RBP into the later-lifecycle-phases' use of DDP. Also, this would reduce the number of different tools that would have to be developed, maintained, installed and applied.

Experience revealed that the combination of these qualitative and quantitative tools involved four kinds of activities:

1. *Embedding* of RBP into DDP. RBP is a qualitative tool, while DDP is quantitative, so overall, this activity involved representing the more restricted data of RBP within the more general data types of DDP.
2. *Extending* DDP with RBP-like capabilities. The RBP tool had some convenient interfaces designed primarily for RBP's qualitative data, but which could with ingenuity be extended so as to operate on DDP's quantitative data.
3. *Extending* RBP with DDP-like capabilities. The DDP tool had areas of flexibility that RBP's designers had not initially thought would be needed, but which RBP users asked for.
4. *Melding* at the RBP/DDP transition. The transition from qualitative to quantitative need not necessarily be an abrupt and unidirectional step between two operating styles. Rather, melding of the qualitative and quantitative data (and concomitant interfaces) can yield increased flexibility, and permit cross checking of later phase details against earlier phase estimates. This is especially critical in today's rapid mission development in which there can be a large variation in the maturity of various spacecraft components – some may be ready for quantitative evaluations while others may still exist in only a qualitative sense.

The net result is a combination that exhibits the best attributes of both qualitative and quantitative risk management tool support. The subsections that follow present some details of these aspects of combination.

2.1. Embedding of RBP into DDP

Overall, DDP's information content is a generalization of RBP's, and hence RBP information is readily embedded in DDP. The key embeddings are listed in the following table:

RBP	DDP
Risk	Failure Mode
Risk *List*	Failure Mode *Tree*
Risk Priority (*enumerated set*)	Failure Mode Impact (*number or string*)
Activity	PACT
Activity *List*	PACT *Tree*
Activity Selection (Boolean)	PACT Selection (Boolean)
Risk/Activity Link (binary)	PACT/Failure Mode Link (quantitative)

All of the RBP concepts and concepts' attributes are present in DDP, but since the RBP information is at a more general or higher level, have different names (e.g., RBP's "risks" are DDP's "Failure Modes"). More significantly, the types of RBP's attributes are encompassed by the types of the corresponding DDP attributes (e.g., RBP's risk prioritization is an enumerated set – high, medium, low, unknown, or not applicable; DDP's Failure Mode impact is a number or string, so strings are used to encode the RBP enumerated set values). Finally, RBP's structures are subsumed by DDP's (e.g., RBP has *lists* of risks; DDP has *trees*).

As a result, it was easy to embed all the RBP information into DDP. The "look and feel" of RBP was recreated as a set of RBP-specific windows, which behind the scenes stored and manipulated the RBP information in the DDP data structures.

2.2. Extending DDP with RBP capabilities

People who had seen RBP's capabilities began requesting that those same capabilities operate on all DDP data, not just data from an RBP session. A straightforward instance of this is described first, in which the RBP capability could, with insight, be applied to several aspects of DDP data. A more involved instance is then described in which the RBP capability itself had to be significantly extended in order to apply successfully to DDP data.

2.2.1. Straightforward transfer of an RBP capability. RBP offers a scrollable list of risk priorities alongside their titles. This inspired the construction of a similar capability within DDP, in which a list is placed alongside DDP's *tree* view. The list is populated with the values of a user-selectable attribute of the nodes displayed in the tree (e.g., if the tree is displaying requirements, the user could select to view the weights [importance] of those requirements in the adjacent list). One of the more intriguing uses of this is to display, in essence, a 1-dimensional vector of quantitative information extracted from a 2-dimensional matrix: When the tree is displaying PACTs (Preventative, Analysis, Control or Test - DDP's acronym for all activities that reduce risk), then populate the list with the effectiveness values of those PACTs against the currently-in-focus Failure Mode. Thus the in-focus Failure Mode is used to select a subset of information, which the RBP capability is able to display.

2.2.2. Extension and transfer of an RBP capability. The RBP prototype used a compact graphical view of the connections between risk and risk-reduction activities. The essence of this view was a column of risks, alongside each of which was a row displaying just those activities that (if chosen to be applied) would mitigate that risk. Prior to combination, DDP had used a grid-based view to display the entire matrix of such information. Despite several conveniences built into DDP's matrix view, the RBP view proved to be a popular alternative, especially given that risk-mitigation matrix is usually sparse.

However, the original RBP view took advantage of the bounded size of the dataset (pre-populated checklists of risks and mitigations), whereas in DDP such information is not so bounded – for example, DDP users can add new Failure Modes. In applications of DDP to date, it has been common for users to define 50 - 100 each of Failure Modes, PACTs and Requirements. Furthermore, DDP involves quantitative data in its matrices – e.g., numerical estimates of how much a PACT (mitigation) reduces a Failure Mode (risk). In order to get the RBP view to work well with DDP datasets, RBP's compact view thus had to be extended to accommodate larger and more detailed quantities of information. Techniques applied included:

- Using dynamic features – e.g., highlighting as the cursor is moved over an item, so that more information could be packed onto the screen and yet remain usable.
- Employing more elaborate layout schemes – e.g., automatically splitting long lists over multiple rows when necessary.
- Switching visual representations – e.g., in place of color (used in RBP to display a small number of discrete measures), use dimension (so as to display DDP's continuous measures).

2.3. Extending RBP with DDP capabilities

DDP capabilities to operate on RBP-level data were also asked for. In contrast with the extensions discussed in the previous section, these generally require less insight and effort to implement, but warrant some consideration as to whether the capabilities need to be suitably restricted.

The RBP data-populators (as distinct from RBP end-users) who were familiar with DDP wanted to use the DDP capabilities to create and edit RBP data, rather than the low-level way provided to get data into RBP. Since RBP data *is* DDP data, this was a simple matter of explaining how the RBP data is organized. No change to the implementation was needed.

The RBP users, many of who had seen DDP, wanted the open-ended nature of DDP even while operating at the early phases where RBP applied. Specifically, they wanted to be able to add their own risks, risk-reducing activities, and connections between them. Implementation of this is underway. The trivial first step of extending the RBP views to pop up RBP-specific data entry and editing screens (which make visible only the RBP-specific subset of data attributes) has been completed. However, further work is required before this capability is released. Notably, people should not be able to accidentally (or deliberately!) corrupt information from the original RBP dataset. To handle this latter concern, the plan is to make use of DDP's versioning capabilities, so that users are free to *override* information within their version space, while the original information is left unchanged in its own version space. This will offer the option of automatically comparing the user's version against the original. The general point to observe is that while it is possible to extend a powerful capability from one tool to another, it is wise to consider the ramifications of doing so, and be prepared to provide suitable restrictions and safeguards.

2.4. Melding at the RBP/DDP transition

As has been described, RBP's information is hosted in the more general DDP tool. What turned out to also be needed is a way to transition *incrementally* from the *qualitative* nature of the RBP information to the *quantitative* measures supported by DDP. Means to address this are as follows.

DDP's editing capabilities are available for users to go in and manually replace the qualitative information with quantitative data. For example, the RBP connections between risks and risk-reducing activities are encoded as textual "*" entries in DDP's PACT x Failure Mode matrix. The user can edit each of these, and enter the numerical effectiveness of PACT against Failure Mode.

When in "DDP" mode using the RBP-inspired compact view of links, color is used to draw attention to the difference between qualitative information and quantitative information. This is also useful for purely DDP applications. During brainstorming sessions, people sometimes know that there is *some* link between (say) a PACT and a Failure Mode, but they do not want to disturb their train of thought to pin down a quantitative value. Instead, they put in some qualitative value, perhaps as simple as "?", and move on. This color-coding helps identify where there are such instances.

An obvious automation to consider is to globally replace qualitative RBP risk prioritizations with quantitative equivalents. For example, the high/medium/low risk prioritizations could automatically be replaced by quantitative impacts (DDP's equivalent of risk priorities) of 0.9/0.3/0.1 (or whatever trio of values the user might prefer). However, there is good reason to stop short of this seemingly obvious step: the RBP risk prioritization is done during the early project phases, and does not explicitly link risks to requirements. When it is time to transition to DDP, risk prioritization should be revisited. In particular, the use of the full DDP methodology, which involves identifying the project requirements, and quantitatively linking the Failure Modes to those requirements, should be employed. The total impact of a Failure Mode is then *computed* as the sum of the impacts it causes against the (weighted) requirements. What is seen as useful is to be able to *compare* the early RBP risk prioritization against the computed Failure Mode impacts. To do this, side-by-side displays could be used to present both qualitative and quantitative measures against the list of Failure Modes, sorted by qualitative measure, and any discrepancies would be immediately obvious. This is yet to be implemented.

To date, implementation of hybrid (mixed qualitative and quantitative) risk management elements has addressed only the bottommost level of the tree-structured data. The plan is to extend DDP's aggregation of quantitative data to also apply to qualitative data, and most especially to mixtures of the two.

3. Related Work and Summary

There are many instances of qualitative summarizations built in to quantitative tools. Some examples taken from the realms of business performance, risk and requirements management are:

- CorVu Corporation's CorManage™ [5] automation of Balanced Scorecard [6] concepts: this uses color-coding to highlight qualitatively different categorizations of quantitative management performance information.
- The Distributed Collaboration and Prioritization Tool of [7] superimposes demarcations of qualitative regions onto quantitative displays of data (e.g., relative probability plotted against relative loss). Similarly, in [8], qualitative demarcations of "High", "Medium" and "Low" regions are placed on 2-dimensional charts displaying the value against cost of candidate requirements.

These are representative of tools that construct qualitative abstractions of quantitative data, a useful way of summarizing datasets so as to support decision-making.

Another commonly used technique is to proffer a qualitative input device that behind the scene translates input into quantitative measures. For example, the Expert system of [9] elicits qualitative inputs from users, and is integrated with Cocomo to yield quantitative outputs (of effort, schedule, and varieties of risk).

The work reported herein represents an advance beyond the capabilities of existing tools, in the following dimensions:

- Spans earlier and later phases in project development, which necessitates the accommodation of both qualitative and quantitative risk management.
- Makes (suitably extended) capabilities from those different phases available to each other. This is primarily a positive consequence of the method by which the combined tool was developed, beginning with separate but complementary tools, and then bringing them together. This encourages the cross-pollination of ideas.
- Offers opportunities for crosschecking qualitative and quantitative information, and for hybrid operation on a mixture of both kinds of information. This means that the transition from qualitative to quantitative need not be a one-way, abrupt step. This is an area in which there is scope for considerable further work to be done.
- Overall, accommodates larger datasets while providing machine support for primarily human directed decision-making.

This effort is a step towards enabling NASA risk management personnel to utilize a single tool throughout the life of a project. This will support 'continuous' risk management, freeing the user from constraints due to purely qualitative or quantitative approaches. It is often tempting to discard qualitative data if it does not fit cleanly into quantitative risk analysis methods. Conversely, if one is too early in a project to perform quantitative risk assessments, it is easy to become discouraged, and not assess risk at all. This tool will enable the user to truly assess risk commensurate with the level of their knowledge, and to refine this assessment as knowledge increases or project circumstances change.

4. Acknowledgements

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

The authors extend thanks to the following: Denise Howard and Chris Hartsough for design and prototyping of the initial RBP prototype, and Julia Dunphy, Stan Eisenbaum, Mark Gibbel, Tom Gindorf, Dan Hoffman, John Kelly, Jim Kiper, Burton Sigal and Robert Wingren for their insights and contributions to the design and implementation of both tools, and M. Greenfield for advocating both qualitative and quantitative risk management and for having the strategic vision to develop tools to accomplish both.

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